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Comprehensive Report to Congress Clean Coal Technology Program

WSA - SNOX Flue Gas Cleaning Demonstration Project

A Project Proposed By Combustion Engineering, Inc.

November 1989

U.S. Department of Energy
Assistant Secretary for Fossil Energy
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1.0 EXECUTIVE SUMMARY

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million to conduct cost-shared Innovative Clean Coal Technology (ICCT) projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) issued by the Department of Energy (DOE) in February 1988 solicited proposals to demonstrate technologies that were capable of being commercialized in the 1990's, more cost effective than current technologies, and capable of achieving significant reduction of sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) emissions from existing coal burning facilities, particularly those that contribute to transboundary and interstate pollution.

In response to the PON, fifty-five proposals were received by the DOE in May 1988. After evaluation, sixteen projects were selected for award. These projects involve both advanced pollution control technologies that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating plant capacity and extend the operationg life of the facility.

One of the sixteen projects selected for funding is the Wet Gas Sulfuric Acid-Selective Catalytic Reduction of NO_x (WSA-SNOX) demonstration project proposed by Combustion Engineering, Incorporated (CE). This project will demonstrate the catalytic removal of NO_x and SO_2 from the flue gas of a utility coal-fired boiler retrofitted with the WSA-SNOX process. The only by-product of the WSA-SNOX process is commercial quality sulfuric acid.

In the WSA-SNOX process, flue gas containing NO_x and SO_2 formed during coal combustion is first processed through particulate removal equipment and heated to reaction temperature. A small quantity of ammonia is then injected into the flue gas and the mixture passes through a NO_x reactor where nitrogen oxides are converted to nitrogen and water vapor. The flue gas leaving the NO_x reactor is further heated and processed through an SO_2 reactor where the SO_2 is converted to sulfur trioxide (SO_3). The flue gas leaving the SO_2 reactor is first cooled by the flue gas coming from the particulate removal unit and then passed through a condensing tower where marketable, high-concentration sulfuric acid is formed. Unconverted ammonia, carbon monoxide and hydrocarbons are oxidized in the SO_2 reactor and essentially all remaining particulates are retained in the reactor's catalyst bed.

The WSA-SNOX process is expected to remove 90+% of the NO_x and 95+% of the SO_x from the flue gas from coal-fired boilers. The process is particularly suitable for retrofitting to cyclone fired boilers and provides a potential means to reduce acid rain producing emissions, while permitting the extensive utilization of high sulfur coal reserves in the United States. It also provides an alternate technology to conventional Flue Gas Desulfurization (FGD) and De-NO_x processes, while requiring lower overall costs and producing no waste products.

The project will be conducted at the 100 megawatt (MW) cyclone coal-fired Niles Station Boiler No. 2, owned by Ohio Edison Company. A 35 MW equivalent slipstream (78,000 Standard Cubic Feet per Minute [SCFM]) will be used for the demonstration project because it is large enough to provide results representative of utility size installations, at a reasonable cost. The plant is located in Niles, Ohio, as shown in Figure 1, and fires bituminous high sulfur (3.76%) coal from southeastern Ohio and western Pennsylvania. The demonstration project will be performed over a forty-five month period and includes design, permitting, construction, testing, data analysis, site restoration and reporting of results.

The total project cost is $31,438,408. The co-funders are the DOE ($15,719,200), CE ($3,332,803), the Ohio Coal Development Office (OCDO) ($7,859,602), Snamprogetti, U.S.A. ($3,332,803), and Ohio Edison Company ($1,194,000). Testing is scheduled to begin in early 1991. Overall project completion is scheduled to occur in early 1993.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the use of coal in a cost-effective and environmentally acceptable manner.

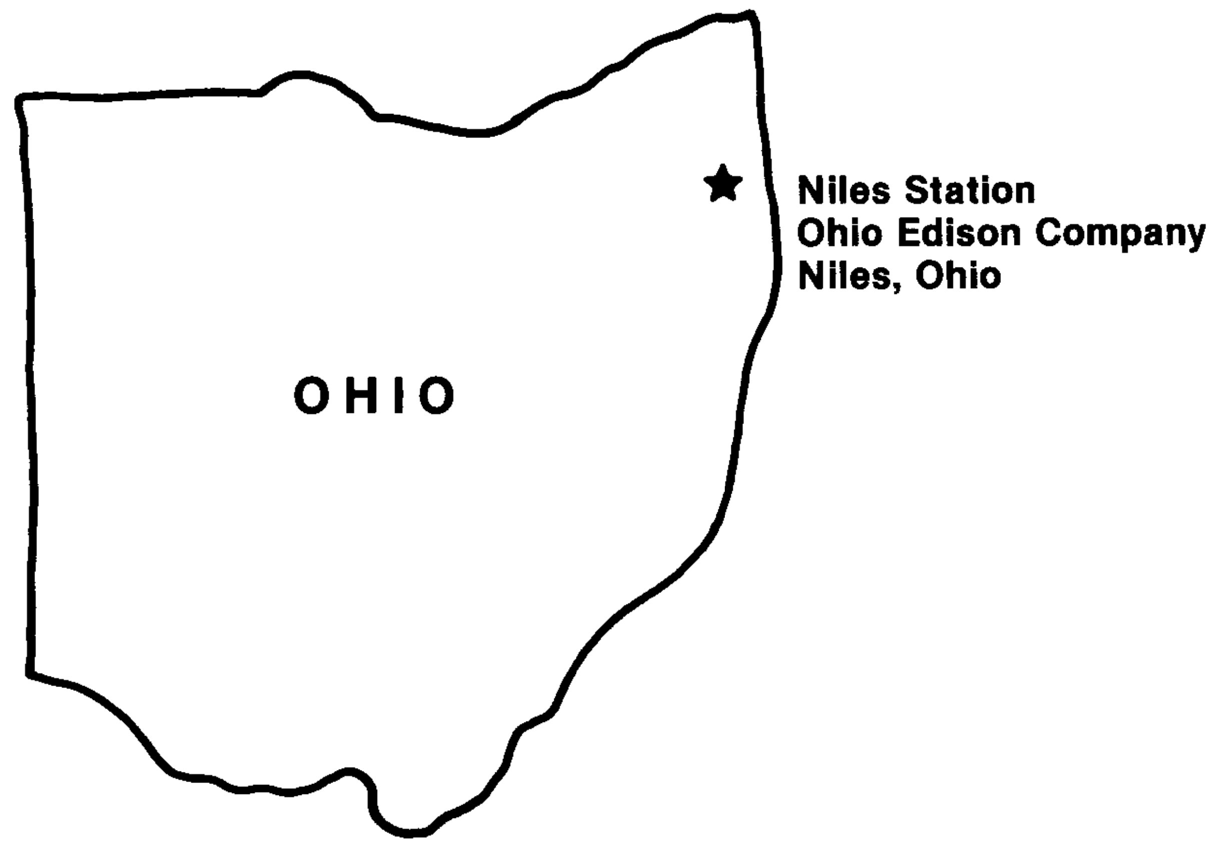

FIGURE 1. COMBUSTION ENGINEERING INC., WSA-SNOX DEMONSTRATION PROJECT LOCATION.

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2.1 Requirement for Report to Congress

In December 1987, Congress made funds available for the ICCT Program in Public Law No. 100-202, "An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million, which will remain available until expended, and of which (1) $50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional $190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional $135,000,000 will be available for the fiscal year beginning October 1, 1989; and (4) $200,000,000 will be available for the fiscal year beginning October 1, 1990. Of this amount, $6,782,000 will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

In addition, after the projects to be funded had been selected, DOE prepared a comprehensive report on the proposals received. The report was submitted in October 1988 and was entitled "Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice (DOE/FE-0114)". Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for ICCT projects, summarizes the project proposals that were received, provides information on the technologies that are the focus of the ICCT Program, and reviews specific issues and topics related to the solicitation.

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on each project selected for award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the Combustion Engineering, Inc. WSA-SNOX Demonstration Project.

2.2 Evaluation and Selection Process

A PON was issued by DOE on February 22, 1988, to solicit proposals for conducting cost-shared ICCT demonstrations. Fifty-five proposals were received. All proposals were required to meet the six qualification criteria provided in the PON. Failure to satisfy one or more of these criteria resulted in rejection of the proposal. Proposals that passed Qualification Review proceeded to

Preliminary Evaluation. Three preliminary evaluation requirements were identified in the PON. Proposals were evaluated to determine whether they met these requirements; those proposals that did not were rejected.

Of those proposals remaining in the competition, each offeror's Technical Proposal, Business and Management Proposal, and Cost Proposal were evaluated. The PON provided that the Technical Proposal was of somewhat greater importance than the Business and Management Proposal and that the Cost Proposal was of minimal importance; however, everything else being equal, the Cost Proposal was very important.

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors," addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with factors involved in the commercialization process. The criteria in this section provided for consideration of (1) the potential of the technology to reduce total national emissions of SO_2 and/or NO_x emissions and to reduce transboundary and interstate air pollution with minimal adverse environmental, health, safety, and socioeconomic (EHSS) impacts; and (2) the potential of the proposed technology to improve the cost-effectiveness of controlling emissions of SO_2 and NO_x when compared to commercially available technology options.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "predemonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Criteria in this category provided for the consideration of the following: the technical readiness for scale-up; the adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; the reasonableness and adequacy of the technical approach; and the quality and completeness of the Statement of Work.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror, and was used as an aid in determining the offeror's understanding of the technical requirements of the PON. The Cost Proposal was reviewed and evaluated to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of the PON.

Consideration was also given to the following program policy factors:

(1) The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility);

(2) The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted SO_2 and NO_x; and

(3) The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of SO_2 and NO_x in terms of facility types and sizes, and coal types.

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

An overall strategy for compliance with the National Environmental Policy Act (NEPA) was developed for the ICCT Program, consistent with the Council on Environmental Quality NEPA regulations and the DOE guidelines for compliance with NEPA. This strategy includes both programmatic and project-specific environmental impact considerations, during and after the selection process.

In light of the tight schedule imposed by Public Law No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic- and project-specific environmental data and analyses as a discrete part of each proposal submitted to DOE.

The DOE strategy for NEPA compliance has three major elements. The first involves preparation of a programmatic environmental impact analysis for public distribution, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis documents that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are considered in the selection process. The second element involves preparation of a preselection project-specific environmental review for internal DOE use. The third element provides for preparation by DOE of publicly available site-specific NEPA documents for each project selected for financial assistance under the ICCT Program.

No funds from the ICCT Program will be provided for detailed design, construction, operation, and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each Cooperative Agreement entered into will require an Environmental Monitoring Plan (EMP) to ensure that significant technology, project, and site-specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, sixteen proposals were selected for negotiation and award. The WSA-SNOX proposal submitted by CE was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

The CE WSA-SNOX project will demonstrate that catalytic reduction of NO_x using ammonia and catalytic conversion of SO_2 to sulfuric acid to reduce NO_x and SO_2 emissions from coal-fired power plants is suitable for retrofit applications. It will be the first commercial scale demonstration of this particular technology that is relevant to utility boilers in the United States. Since the technology is modular, it can be readily scaled to any utility application.

The advantages of the WSA-SNOX process over conventional pollution control processes is the combined removal of SO_2, NO_x, and particulates without generation of additional liquid or solid wastes, and with production of marketable sulfuric acid by-product. In addition, lower plant heat consumption rates can be expected, and capital and operating costs are projected to be lower, making the process attractive for both new and retrofit applications.

The demonstration will be conducted at Ohio Edison's Niles Station Boiler No. 2 using bituminous coal from southeastern Ohio and western Pennsylvania (3.76% sulfur). The unit is a pre-NSPS 100 MW cyclone coal-fired utility boiler. This type boiler produces high levels of NO_x and SO_2, believed to be the main cause of acid rain, and therefore, a successful demonstration on this unit will make WSA-SNOX technology attractive for retrofit applications. A 35-MW equivalent slipstream from the unit will be used for the demonstration. This size demonstration is large enough to use full-size components and provide test results representative of a utility scale WSA-SNOX facility, yet small enough to be economical while causing minimal downtime.

The goal of this program is to prove the technical and economic feasibility of the WSA-SNOX technology. If successful, it will achieve 90+% NO_x removal, 95% SO_x removal, 99+% particulate removal, and production capability of commercial quality sulfuric acid, at lower capital and operating/maintenance (O&M) costs than other systems.

3.1.1 Project Summary

Project Title:	WSA-SNOX Flue Gas Cleaning Demonstration Project
Proposer:	Combustion Engineering, Inc.
Project Location:	Niles, Ohio Ohio Edison Niles Station Trumbull County
Technology:	Flue gas cleanup by catalytic reduction using ammonia for NO_x control and sulfuric acid production by catalytic conversion of SO_2 to SO_3 for SO_2 control; condensation of SO_3 and water vapor to high concentration H_2SO_4
Application:	New and Retrofit of coal-fired utility and industrial boilers and applicable to new boilers
Types of Coal Used:	Southeastern Ohio and western Pennsylvania coals (3.76 % sulfur)
Product:	Environmental control technology
Project Size:	35 MWe (78,000 SCFM)
Project Start Date:	January 1990
Project End Date:	September 1993

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Combustion Engineering, Inc.
Proposed Co-Funders:	U.S. Department of Energy Ohio Coal Development Office Ohio Edison Company Snamprogetti, U.S.A.
Proposed Project Cost:	\$31,438,408

Proposed Cost Distribution:

Participant Share(%)	DOE Share(%)
50%	50%

3.2 WSA-SNOX Process

3.2.1 Overview of Process Development

The WSA-SNOX technology was developed by Haldor Topsoe A/S, a major supplier of catalysts and process technology. In 1963, Haldor Topsoe designed its first plant in France (150,000 SCFM industrial application) using the WSA-1 process without selective catalytic reduction. The plant operated for eight years.

In 1980, two WSA plants (each, 1,200 SCFM industrial applications) were commissioned in Sweden. These plants, as well as the plant in France, utilized the WSA-1 absorption tower, which uses hot circulating sulfuric acid as the coolant. Haldor Topsoe has since developed the WSA-2 tower, which is a vertical falling film condenser cooled by air or gas on the outside of the tubes.

The first WSA-2 plant was commissioned in Sweden in 1986 and is capable of recovering more than 95% of the SO_2 in the gas as 95 to 96% concentrated high purity sulfuric acid. It treated 7,500 SCFM of dust-free offgas with 0.5-1.5% SO_2 from combustion of molybdenum sulfide. A full-scale WSA-2 plant, near start-up in Taiwan, will treat about 78,000 SCFM of flue gas from the combustion of black liquor, a by-product of the paper of the manufacturing process.

Also in the early 1980's, Haldor Topsoe developed the selective catalytic reduction catalyst for reducing NO_x in flue gases and exhaust gases. Testing of the catalyst for use in power plants was first performed on a pilot scale at a coal-fired power plant. Subsequent testing has been performed since 1986 in a larger scale pilot unit (6,200 SCFM) in Denmark.

The WSA-SNOX process, which uses selective catalytic reduction, SO_2 conversion to SO_3, and the WSA-2 tower condensing technology has been undergoing testing since 1987 in a third pilot plant in Denmark. This 3 MW scale pilot plant (6,200 SCFM) simulates the process proposed for the Niles Station demonstration. A larger pilot plant has been ordered by a sister company of Snamprogetti to demonstrate the integrated version of the WSA-SNOX process including particulate removal; the plant is scheduled for start-up in 1990 and will treat 62,000 SCFM of flue gas with 0.3-0.4% SO_2 from combustion of petroleum coke in a power plant at Gela in Sicily, Italy.

3.2.2 Process Description

The WSA-SNOX process combines Selective Catalytic Reduction (SCR) and sulfuric acid production technologies to remove nitrogen oxides and sulfur oxides from flue gases. As shown in Figure 2, flue gas leaving the boiler is cooled in the air heater by cooling air exiting the WSA-2 tower. The flue gas is further cooled in a trim cooler, where the heat recovered from the cooling of the flue gas is used to produce low pressure process steam. The flue gas then passes through a baghouse or electrostatic precipitator for particulate removal to minimize fouling of the catalyst in the SO_2 converter by fly ash particulates. Next, a gas-to-gas heat exchanger is used to heat the flue gas entering the NO_x reactor and cool the gas exiting the SO_2 reactor. The heated incoming flue gas is then mixed with ammonia and enters the SCR reactor where the ammonia and nitrogen oxides are converted to nitrogen and water vapor. Following NO_x conversion, the flue gas is heated by a burner prior to entering the SO_2 reactor where SO_2 is oxidized to SO_3.

In the catalyst bed of the SO_2 reactor, the ammonia is decomposed and any uncombusted carbon in the flue gas is also oxidized. In addition, any remaining particulates are retained in the catalyst bed. The processed flue gas exits the reactor and, as discussed above is cooled against incoming gas in the gas to gas heat exchanger. This cooling process also allows the SO_3 to hydrolyze to sulfuric acid gas. The gas then passes through the WSA-2 tower prior to

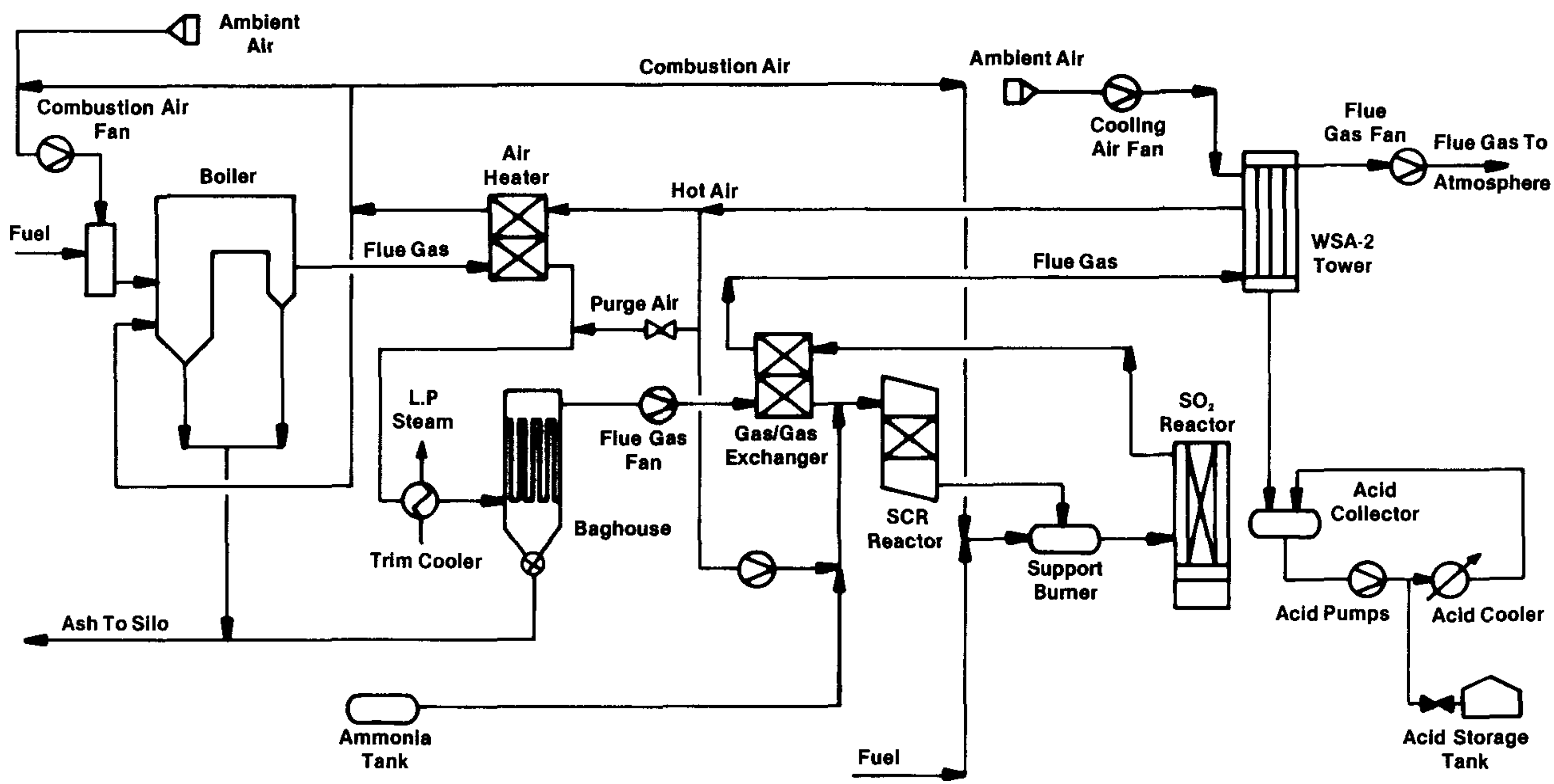

FIGURE 2. WSA-SNOX PROCESS GENERIC FLOW DIAGRAM.

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discharge to the atmosphere via the stack. In the WSA-2 tower, the vapor is condensed, concentrated to 95% sulfuric acid, and then pumped to a storage tank.

The net effect of this technology is a greater than 90% NO_x and 95% SO_x removal, the removal of essentially all particulates, and the production of high purity marketable sulfuric acid without increasing plant emissions.

3.2.3 Application of Process in Proposed Project

The Niles Station Boiler No. 2 is a nominal 100 MW coal-fired cyclone boiler equipped with an electrostatic precipitator. The installation of the WSA-SNOX system will require that a branch line (slipstream) of the flue gas (78,000 SCFM), equivalent to about 35 MWe, be taken off just before the electrostatic precipitator. This branch line containing baghouse, flue gas fan, gas/gas heat exchanger, SCR reactor, flue gas heater, SO_2 reactor, WSA-2 tower, ductwork and dampers will be utilized to perform the demonstration. Figure 3 is an overall process flow diagram for the proposed project.

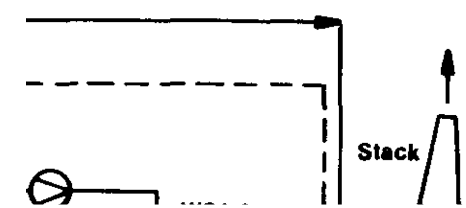
The specific objectives of the demonstration at Niles Station are to: (1) demonstrate the feasibility of the WSA-SNOX process as applied to coal-fired power plants, (2) achieve 95% SO_x removal and 90+% NO_x removal at various loads and with varying fuel composition, (3) demonstrate the commercial quality of the sulfuric acid produced, (4) determine the capacity and life limitations of the equipment and materials and (5) confirm O&M costs.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new technology, there is some risk. However, as described previously, much prior work has been performed on the individual portions of the process. The technology and catalysts used have been demonstrated in pilot and commercial plants. Also, several WSA-SNOX pilot plants have been built and are in use. Further, the sulfuric acid catalyst is being used in more than 100 SO_2 converters in industrial sulfuric acid plants.

After reviewing the results of the development work, an acceptable risk factor has been assigned to this process. No objectionable ammonium sulfate deposition


Stack

is expected to take place in the WSA tower because any trace ammonia will be reacted in the SO_2 reactor. However, the low dust loading specified for the baghouse, to limit subsequent SO_2 catalyst fouling, may prove to be difficult to ensure. This is not considered to be a high risk because of the required low bag filter dust loading, to avoid catalyst fouling, has been achieved on the 3 MW Danish test unit. Further, the bag filter supplier is confident that the desired dust loading is obtainable.

In addition to the technical risk factors described above, a certain amount of economic risk also exists for this project.

- o The life of the SCR catalyst has not been fully proven for large-scale fossil energy applications like the WSA-SNOX process. In a worst-case scenario, short catalyst life would translate to excessively high O&M costs, which could adversely impact WSA-SNOX commercialization.

- o Short bag life and/or low efficiency particulate removal could lead to high capital and O&M costs related to catalyst and bag regeneration or replacement.

- o Sulfuric acid produced by the process might not be of sufficient quality to be saleable, which would change it from a by-product to a waste stream.

However, as previously mentioned, a great amount of pilot scale testing has been done to obtain a reasonable determination of expected catalyst and bag life and sulfuric acid quality. An acceptable economic risk has therefore been assigned to this project.

3.3.1.1 Similarity of the Project to Other Demonstration/ Commercial Efforts

The principle systems that make up the WSA-SNOX process are particulate removal, SCR, and the WSA conversion of SO_2 to sulfuric acid. The particulate removal system utilizes either a baghouse or an electrostatic precipitator (ESP), and is essentially the same as commercially available baghouses and ESPs. The strength of the WSA-SNOX process is in its ability to remove SO_2 and NO_x from flue gas.

The SCR portion of the WSA-SNOX process, the NO_x removal, is similar to two other ICCT demonstration projects: the Southern Company Services (SCS) Selective Catalytic Reduction Demonstration Project proposed for the Gulf Power Company Plant Crist, and the Babcock & Wilcox (B&W) SOX-NOX-ROX Box (SNRB) Project proposed for the Ohio Edison Company R.E. Burger Station. In addition, many plants in Europe and Japan have successfully used SCR to reduce NO_x emissions. However, use of SCR with U.S. coals is not well established. In particular, the proper selection of catalyst and substrate configurations for optimum economic use is still in development. The WSA-SNOX demonstration at Ohio Edison will be the first utility demonstration of the selected Halder-Topsoe catalyst on U.S. coals.

The uniqueness of the WSA-SNOX process is that sulfur oxides are not only removed from flue gas, they are converted to and recovered as sulfuric acid, one of the most important industrial chemicals. The SCS project does not deal with SO_2 emissions at all, while the B&W process removes SO_2 with a dry sorbent which must be subsequently disposed of by landfill. There is no similar process under development for removal of SO_2 from flue gas by conversion into marketable sulfuric acid by-product.

The technology owner of the WSA-SNOX process, Snamprogetti, is demonstrating this technology outside the U.S., for a variety of industrial applications. A 3 MWe WSA-SNOX demonstration plant located in Skaerbaekvaerket, Denmark, has been operating since 1987. This plant exactly simulates the process and all process steps proposed for the larger Ohio Edison demonstration, except the coal used in the 3 MWe unit contains less sulfur.

Other projects similar to the Ohio Edison demonstration include the 78,000 SCFM WSA-SNOX plant under construction in Taiwan for Formosa Fiber and Chemicals Corporation and the 62,000 SCFM WSA-SNOX plant under design in Sicily. Differences from the Ohio Edison demonstration are that the Taiwan plant will remove SO_x from the flue gas of a pulp and paper mill black liquor boiler, while the plant in Sicily will remove NO_x and SO_x from the flue gas of a power plant that can fire oil or petroleum coke as well as high sulfur coal.

3.3.1.2 Technical Feasibility

The WSA-SNOX process has been under development since 1963. The technology has been tested and successfully demonstrated in pilot units. The sulfuric acid catalyst used in the process is used in more than one hundred sulfuric acid converters. In addition, confidence in the process exists as is demonstrated by the construction now underway of large scale prototype projects in Taiwan and Italy for slightly different applications, and the proposed design of a 300 MW coal fired electric utility plant in Denmark.

The experience of CE and Snamprogetti combined with the successful test work and commercial operation of the process indicate that the WSA-SNOX technology is feasible and that this demonstration should achieve its goal of 90% NO_x removal and 95% SO_x removal.

3.3.1.3 Resource Availability

Adequate resources are available for this project over the forty-five month demonstration period. CE, Snamprogetti and the other co-funders have committed adequate funds, as discussed in Section 6.1, to cover the proposed project cost. They have also dedicated sufficient personnel to conduct the demonstration program. Ohio Edison Company personnel will operate the plant. The skilled and unskilled labor required for construction and operation of the project will be readily obtainable, since the Niles Station is located in an industrial region that has a large population of qualified people.

Sufficient space is available at the Niles Station for erection of the demonstration equipment. Neither the quantity nor the quality of the coal now being burned by the Niles Station boiler No. 2 will change during the demonstration period, and the project will use the existing coal handling system.

The resources required for the demonstration include ammonia, concentrated sulfuric acid for startup, the SO_2 catalyst, electrical power, cooling water, and #2 fuel oil or natural gas. Ammonia, sulfuric acid and the SO_2 catalyst are commercially available and can be readily supplied in the quantities required. Electrical power, cooling water and fuel oil can be supplied in the required quantities by the existing plant systems. Natural gas (fuel oil replacement) is currently at the plant boundary and the economics of a tie-in line is being evaluated.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

As mentioned previously, the test boiler is a 100 MW utility unit, but the demonstration will be conducted using a 35 MW equivalent slipstream. There is essentially no scale-up risk in designing larger commercial WSA-SNOX units because the main items of process equipment are modular in design. Scale-up of the WSA-SNOX process simply consists of adding additional modules. This was demonstrated by the scale-up of WSA-SNOX plant in Sweden. The plant was scaled-up by a factor of 500, based on a previous demonstration in a pilot plant. The large plant has been operating successfully since initial startup.

Based on the above, the risk of scale-up is considered to be minimal and the demonstration is expected to prove the applicability of the WSA-SNOX technology for retrofit on pre-NSPS boilers without further demonstration.

3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

This project will demonstrate at utility scale a new flue gas clean-up technology for removal of acid rain causing emissions. This technology can enhance the use of medium and high sulfur coals under conditions requiring compliance with environmental control. The commercialization of the WSA-SNOX technology requires a comprehensive data base for coal-fired applications that demonstrate the emission control, performance, reliability and cost effectiveness of the technology. The suitability of the WSA-SNOX process for retrofit to utility boilers will be fully established when it is demonstrated that NO_x and SO_x can be removed from flue gas to required compliance levels at overall favorable economics when compared to current flue gas clean-up technology.

3.3.3.1 Applicability of the Data to be Generated

In order to produce accurate and reliable technical and economic performance data, the demonstration will be fully instrumented and will use automated data collection techniques. The monitoring of key parameters will be performed continuously using automatic multi-point analyzers. These analyzers will be supplemented by manual sampling and analysis for calibration purposes. Emissions data at various plant loads will be compared with mass balance data.

Detailed mechanical inspections will be conducted to evaluate the behavior of construction materials. Further, failed components, if any, will be analyzed to prevent recurrence.

The concentration of product sulfuric acid will be monitored continuously to determine the purity and commercial quality of the acid.

The tests that are planned during the demonstration will determine the following:

- Bag filter efficiency, cleaning frequency, pressure drop and bag life.
- SCR reactor NO_x removal efficiency and pressure drop.
- SO_2 converter performance, pressure drop and temperature profile.
- Catalyst cleaning system efficiency and abrasion loss of catalyst.
- WSA-2 tower performance.

3.3.3.2 Identification of Features That Increase Potential for Commercialization

Once commercially proven, the WSA-SNOX process will provide an economical and technically acceptable system for the simultaneous control of NO_x, SO_x and particulates. The modest space requirement and competitive capital and operating cost as well as the production of a marketable commodity (H_2SO_4) make the WSA-SNOX technology attractive for new and retrofit applications.

A WSA-SNOX process installation would consist largely of proven, commercially available equipment such as bag filters, blowers, reactors, pumps, etc. The only novel item of equipment is the WSA tower, which as previously mentioned, has been tested extensively in European applications.

In summary, commercialization of the technology will be aided by:

- Simultaneous removal of 90+% NO_x, 95% SO_x and essentially all particulate matter.
- Lower per ton SO_2 removal costs for high sulfur coals.
- Lower predicted overall station heat consumption rate from integration of the WSA-SNOX unit with the combustion air preheat system. This due to recovery of the heat released in the SO_2

oxidation step and the WSA process, greater thermodynamic efficiency resulting from lower allowable flue gas stack temperatures once SO_x species have been removed by the WSA-SNOX process.

- No increase in solid plant wastes because the WSA-SNOX is a non-sorbent process.

- Production of marketable sulfuric acid.

The success of this demonstration will establish that the WSA-SNOX process is an effective, reliable, and economic approach to the control of the two major pollutants associated with acid rain. Accordingly, this technology has the potential to significantly penetrate the large pre-NSPS boiler market for all design types of boilers (cyclone, stoker and pulverized coal).

3.3.3.3 Comparative Merits of Project and Projection of Future Commercial Economics and Market Acceptability

Available methods to control NO_x and SO_x are not as effective for use in cyclone fired boilers. Cyclone fired boilers produce relatively low fly ash loadings and therefore, are not very suitable for sorbent injection. Wet scrubbing of SO_2 is viable, but these systems require high capital costs, require large site space requirements, reduce power plant availability, reduce power plant electrical output and increase spent material production. Further, low NO_x burners and overfire or concentric air additions are not compatible with the operating characteristics of the cyclone chamber. Consequently, there is a need for a new technology that is efficient, economical and reliable that can be used in retrofit applications.

The WSA-SNOX process combines NO_x, SO_x and particulate matter removal. The system will reduce these emissions while lowering fuel usage, improving station heat rate and producing a marketable by-product; sulfuric acid. Since this process sees only the flue gas, the WSA-SNOX technology is applicable to all electric power plants and industrial/institutional boilers no matter what fuel is fired as long as NO_x and SO_x are to be removed. The only limit is that a moderate amount of space is needed near the boiler flue duct so that the flue gas can be economically transported to the SNOX unit, processed and returned to the stack.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with NEPA, cited Section 2.2, contains three major elements. The first element, the Programmatic Environmental Impact Analysis (PEIA), was issued as a public document in September 1988. In the PEIA, the Regional Emission Database and Evaluation System (REDES), a model developed by DOE at Argonne National Laboratory, was used to estimate the environmental impacts that could occur by the year 2010 if each technology were to reach full commercialization and capture 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative, which assumes that use of conventional coal technologies continues through 2010 with new plants using conventional flue gas desulfurization controls to meet New Source Performance Standards.

In the PEIA, the expected performance characteristics and applicable market of the WSA-SNOX technology were used to estimate the environmental impacts that could result if the WSA-SNOX technology were to reach full commercialization in 2010. The REDES computer model was used to project the impacts of the WSA-SNOX technology as compared to the no-action alternative.

Projected environmental impacts from maximum commercialization of the WSA-SNOX technology into national and regional areas in 2010 are given in Table 1. Negative percentages indicate decreases in emissions or wastes. The information presented in Table 1 represents an estimate of the environmental impacts of the technology in 2010. These results should be regarded as approximations of actual impacts.

Table 1: Projected Environmental Impacts in 2010
(Percent Change in Emissions and Solid Wastes)

Region	(SO_2)	Sulfur Dioxide (NO_x)	Nitrogen Oxides Solid Waste
National	-56	-20	0
Northeast	-76	-50	0
Southeast	-63	-26	0
Northeast	-12	- 8	0
Southwest	-29	-13	0

Source: Programmatic Environmental Impact Analysis (DOE/PEIA-0002), U.S. Department of Energy, September 1988.

As shown in Table 1, significant reductions of SO_2 and NO_x are projected to be achievable nationally, due to the capability of the WSA-SNOX process to remove 95% of SO_2 and 90% of NO_x emissions from coal-fired boilers and the wide potential applicability of the process. No changes in solid wastes are anticipated because the technology produces no dry solid waste product. The REDES model predicts greatest environmental impacts will be felt in the Northeast because of the large amount of coal-fired capacity there that can be retrofitted with the WSA-SNOX process. The least impact occurs in the Northwest because of the minimal use of coal there. The national quadrants used in this study are shown in Figure 4.

The second element of DOE's NEPA strategy for the ICCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as a part of each proposal. This analysis, for internal DOE use only, contained a discussion of site-specific EHSS issues associated with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative processes reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the local environment, and a list of permits that must be obtained to implement the proposal, were included. It also contained options for controlling discharges and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based on this analysis, no environmental, health, or safety issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the WSA-SNOX demonstration facility.

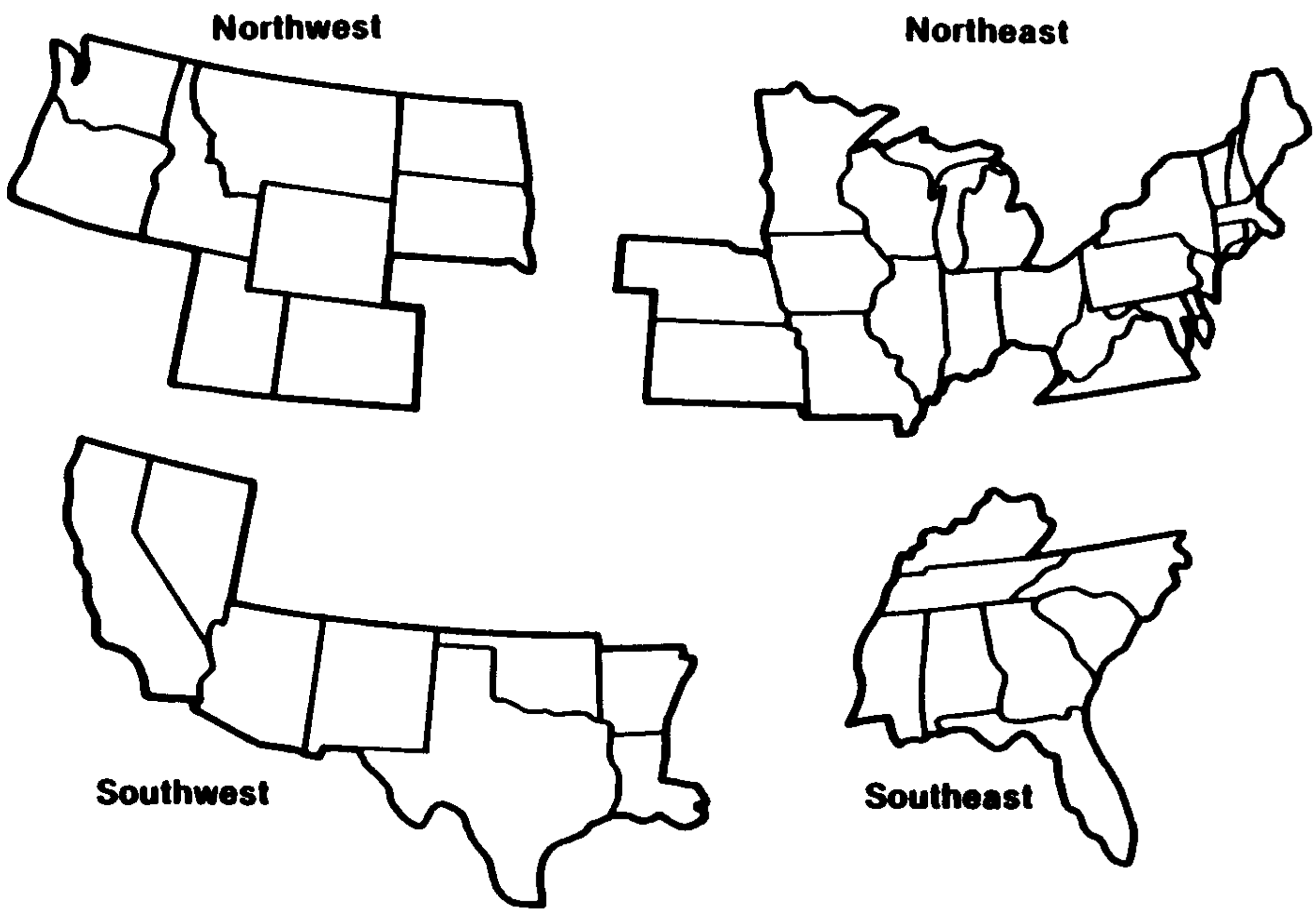


FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

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As the third element of the NEPA strategy, the Participant (CE) will be required to submit the environmental information specified in Appendix J of the PON. This detailed site- and project-specific information will be used as the basis for the development of the site-specific NEPA documents to be prepared by DOE. These documents will be completed and approved in full conformance with the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR Parts 1500-1508) and DOE guidelines for NEPA compliance (52 FR 47662, December 15, 1987) before federal funds are provided for detailed design, construction, and operation.

In addition to the NEPA requirements, the Participant must prepare and submit an Environmental Monitoring Plan (EMP). Guidelines for the development of the EMP are provided in Appendix N of the PON. The EMP is intended to ensure that significant technology-, project-, and site-specific environmental data are collected and disseminated to provide health, safety, and environmental information should the technology be used in commercial applications.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by the Participant's (CE's) Project Manager. He will be the principal contact with DOE for matters regarding the administration of the agreement. The DOE Contracting Officer is responsible for all contract matters and the DOE Contracting Officers Technical Representative (COTR) is responsible for technical liaison and monitoring of the project.

Assisting the CE Project Manager will be a Deputy Project Manager from Snamprogetti who will ensure that the design, procurement and construction work fulfills the requirements of the WSA-SNOX technology.

A Participants Advisory Committee will be formed and be composed of personnel from CE, Snamprogetti, DOE, Ohio Edison, and OCDO. This Committee will meet as needed to review the project, assess plans and provide advice on correcting any deficiencies. The Participants Advisory Committee is intended to be a working group of personnel directly involved in the project and will ensure that the objectives of each participating organization will be met. The Participants Advisory Committee will not direct CE.

In addition to DOE, CE, and Snamprogetti, the project co-funders are Ohio Edison and OCDO.

5.2 Identification of Respective Roles and Responsibilities

DOE

The DOE shall be responsible for monitoring all aspects of the project and for granting or denying approvals required by this Cooperative Agreement. The DOE Contracting Officer is the authorized representative of the DOE for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a COTR who will be the authorized representative for all technical matters and will have the authority to issue "Technical Advice" which may:

- o Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry which assist in accomplishing the Statement of Work.

- o Approve those technical reports, plans, and technical information required to be delivered by the Participant to the DOE under this Cooperative Agreement.

The DOE COTR does not have the authority to issue any technical advice which:

- o Constitutes an assignment of additional work outside the Statement of Work.

- o In any manner causes an increase or decrease in the total estimated cost, or the time required for performance of the Cooperative Agreement.

- o Changes any of the terms, conditions, or specifications of the Cooperative Agreement.

- o Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

All Technical Advice shall be issued in writing by the DOE COTR.

Participant

The Participant (CE) will be responsible for all aspects of project performance under this Cooperative Agreement as set forth in the Statement of Work.

The Participant's Project Manager is the authorized representative for the technical and administrative performance of all work to be performed under this Cooperative Agreement. He will be the single authorized point of contact for all matters between the Participant, DOE, and co-sponsors.

The Deputy Project Manager from Snamprogetti will work closely with the Combustion Engineering Project Manager to assure that program activities are conducted within the schedule and operating requirements of the plant.

The Project Team will also include a Project Engineer. The Project Engineer will report to the Project Manager and will be responsible for all technical work, designation of work packages, engineering schedules, drawing submittals, field liaison and direction of all design work. Also, he will oversee the Lead Discipline Engineers.

Also assisting the Project Manager will be a Project Administrator who will be responsible for overall administrative functions, including conformance of contract documents, issuance of instructions to all participating departments, release of contract requisitions for material procurement, procurement monitoring, expediting and issuance of invoicing instructions.

A complete Project Organization is shown in Figure 5.

5.3 Summary of Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement during the forty-five month demonstration period is divided into three Phases. Those phases are:

- Phase I: Design and Permitting (Budget Period 1)
- Phase IIA: Long Lead Procurement (Budget Period 1)
- Phase IIB: Construction and Start-Up (Budget Period 2)
- Phase III: Operation, Data Collection, Reporting and Disposition (Budget Period 3)

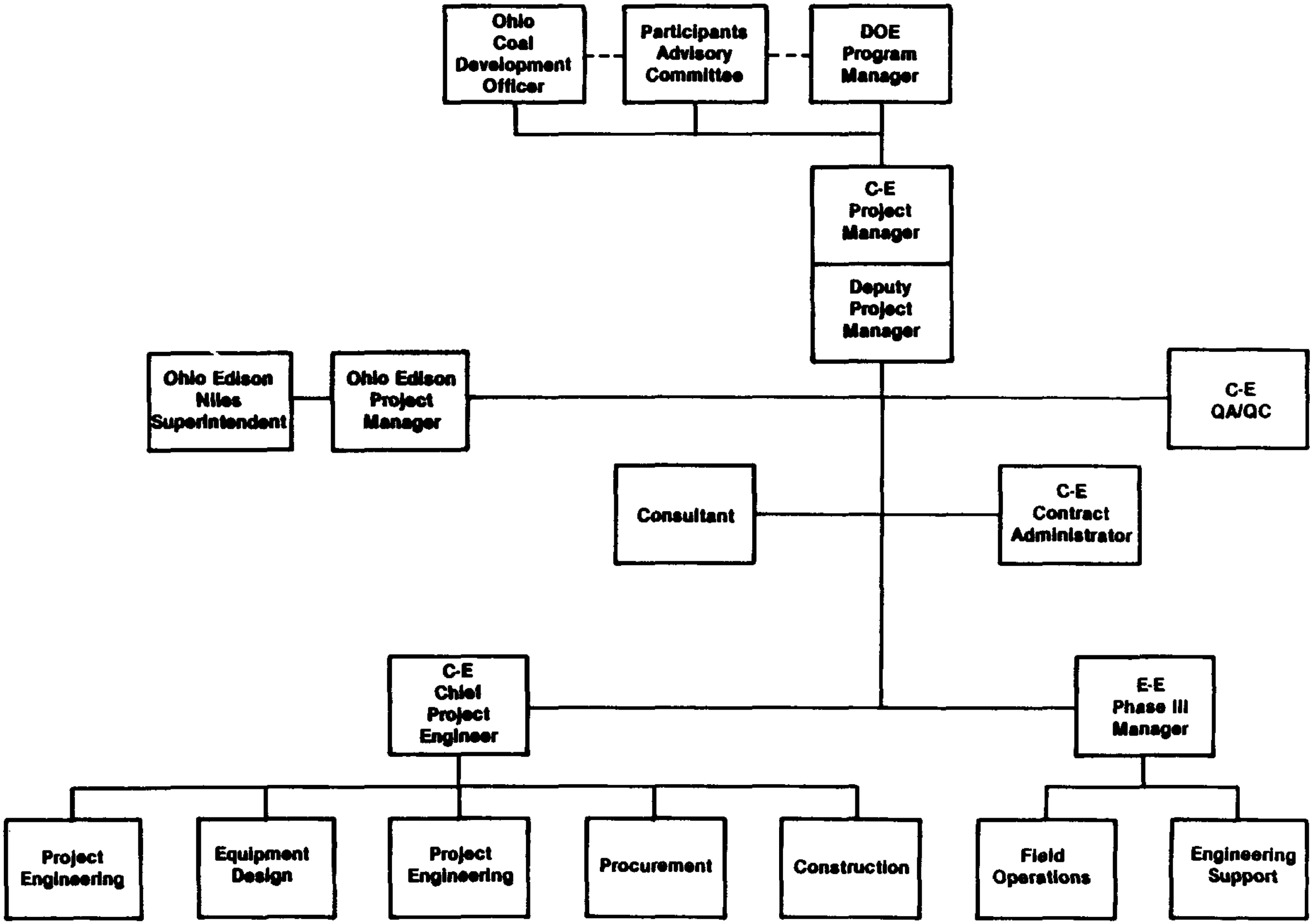

FIGURE 5. PROJECT ORGANIZATION FOR WSA-SNOX DEMONSTRATION.

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As shown in Figure 6, the total project encompasses a forty-five month period. There will be a five month overlap between Phases I and II and Phase III will start upon completion of Phase II.

Three budget periods will be established. The initial budget period will also include certain recognized costs incurred prior to the award of the Cooperative Agreement. Consistent with P.L. 100-202 as amended by P.L. 100-446, DOE will obligate sufficient funds to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost and environmental monitoring aspects of the project will be prepared by CE and provided to DOE.

5.4 Key Agreements Impacting Data Rights, Patent Waivers, and Information Reporting

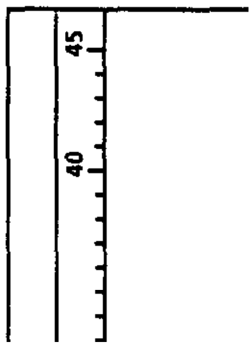
CE's incentive to develop this process is to realize retrofit business from, and produce new designs for, the utility and power boiler industry with respect to SO_2 and NO_x abatement technology. The key agreements with respect to patents and data are:

- Patent waiver requests by CE, Snamprogetti USA, and Haldor Topsoe have been made, which, if granted, would give each party rights to inventions made by the respective parties. The allocation of rights as between CE and its major subcontractors, Snamprogetti, and Haldor Topsoe, is not known at this time.

- Standard data provisions are included, giving the Government the right to have delivered, and use, with unlimited rights, all technical data first produced in the performance of the Agreement.

- Rights in background patents and background data of CE and Snamprogetti and all of their subcontractors are included to assure commercialization of the technology.

CE will make such data, as is applicable and non-proprietary, available to the DOE, Environmental Protection Agency, Ohio Environmental Protection Agency, other interested agencies, and the public.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5.5 Procedures for Commercialization of the Technology

The WSA-SNOX technology is applicable to new and retrofit coal-fired power plants. Over 1000 electric power generating units exist in the United States which are of pre-NSPS design. Of these, about 410 units are 100 MW in size or larger and were placed in service between 1955 and 1975. These units account for about 60% of the total national SO_2 emissions. Many of these units are located in the states of Pennsylvania, West Virginia, Kentucky, Illinois, Indiana, Missouri, Ohio and Tennessee. These regions also produce sulfuric acid from elemental sulfur.

The total potential retrofit market applicable to this technology is estimated to be almost $45 billion. The estimated production of sulfuric acid from this potential market is estimated to be about 25 million short tons per year, which is less than current United States demand and less than projected future needs. The projected yearly market for this technology is estimated to be about $2.25 billion. It is believed that the proposing organizations are financially and physically capable of adapting to meet this market demand.

The project team is composed of two of the most prominent companies in their specialty area: Combustion Engineering has over fifty years experience in the design, manufacture, and construction of coal-fired utility and industrial steam generators and in commercializing advances in this technology with a market share of about 40% in the free world; Snamprogetti is a major European design and construction firm for commercial size chemical plants, gas treating facilities, and power generating units that is one of the major subsidiary companies of ENI, the Italian National Oil and Energy Organization. These two companies, with their vast production facilities and marketing ability, clearly have the potential to effectively commercialize the WSA-SNOX process.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $31,438,408. The Participant contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	$264,455	50%
Participant	$264,455	50%
PHASE I		
Government	$2,058,850	50%
Participant	$2,058,857	50%
PHASE IIA		
Government	$2,037,392	50%
Participant	$2,037,393	50%
PHASE IIB		
Government	$7,148,255	50%
Participant	$7,148,255	50%
PHASE III		
Government	$4,210,248	50%
Participant	$4,210,248	50%
TOTAL PROJECT		
Government	$15,719,200	50%
Participant	$15,719,208	50%
TOTAL	$31,438,408	100%

Cash contributions will be made by the co-funders as follows:

DOE:	$15,719,200
OCDO:	$7,859,602
Ohio Edison	$1,194,000
CE:	$3,332,803
Snamprogetti	$3,332,803
TOTAL	$31,438,408

At the beginning of each budget period, DOE will obligate sufficient funds to pay its share of expenses for that budget period.

6.2 Milestone Schedule

The overall project will be completed in 45 months after award of the Cooperative Agreement. The Project Schedule, by phase and activity, is shown in Figure 6.

Phase I, which involves permitting, preliminary and final design, will start immediately after award and continue for nine months. Phase IIA, will overlap Phase I and consist of long-lead procurement. Phase IIB, which consists of equipment fabrication, construction and start-up, and site restoration, if required will follow Phase IIA and continue for eleven months. Upon completion of Phase IIB, in the twentieth month, Phase III will start. Phase III, which consists of execution of the test program, analysis and assessment of the data, site restoration and production of the final report, will last for twenty-five months.

6.3 Repayment Plan

Based on DOE's policy as stated in Section 6.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Participant has agreed to repay the Government in accordance with the stated Recoupment/Repayment Plan to be included in the final negotiated Cooperative Agreement.